Energy, Mines and Resources Canada
Energie, Mines et Ressources Canada

CANMET
Canada Centre for Mineral and Energy Technology
Centre canadien de la technologie des minéraux et de l'énergie

NOTES ON DENISON MINE PILLAR-BACKFILL CONFINEMENT TESTS

G. SWAN

ELLIOT LAKE LABORATORY

MAY 1985

This document is an unedited work report prepared primarily for information and internal operating purposes. It does not necessarily reflect the views of the Canada Centre for Mineral and Energy Technology (CANMET)

Ce document de travail a été préparé principalement à des fins de diffusion et de renseignements internes. Il ne reflète pas nécessairement les opinions du Centre canadien de la technologie des minéraux et de l'énergie (CANMET)

MICROMEDIA

MINERALS RESEARCH PROGRAM
MINING RESEARCH LABORATORIES
DIVISION REPORT MRP/MRL 85-78(TR)

NOTES ON DENISON MINE PILLAR-BACKFILL CONFINEMENT TESTS

by

Graham Swan*

ABSTRACT

In response to a request from Denison Mine's geotechnical consultants, S.R.K., CANMET's Mining Research Laboratory agreed to perform a series of pillar confinement tests using cemented tailings. The tests, conducted on laboratory-size specimens in a soft, 500 kN loading frame, demonstrated an as yet unexplained mechanism to achieve stable pillar post-failure. While only limited data is still available, the conclusion has been made that nominally "soft" backfills can control the violence of failure in the laboratory. The significance of this is discussed in relation to the mine-size problem of controlling pillar bursts.

*Research Scientist, Elliot Lake Laboratory, CANMET, Energy, Mines and Resources Canada.

OBSERVATIONS SUR LES ESSAIS DE CONFINEMENT DES PILIERS PAR LE REMBLAYAGE À LA MINE DENISON

par

Graham Swan*

RÉSUMÉ

À la demande des experts-conseils en géotechnique de Stessen, Robertson and Kirsten (S.R.K.) à la Denison Mines, le Laboratoire de recherche minière de CANMET a accepté d'effectuer une série d'essai sur le confinement des piliers à l'aide de remblais de stériles cimentés. Les essais, effectués sur des échantillons à l'échelle du laboratoire dans un banc de chargement mou de 500 kN, ont démontré un moyen inexpliqué jusqu'ici pour parvenir à conserver des piliers stables après rupture. Bien qu'il n'y ait qu'un nombre limité de données encore disponibles, on en est arrivé à la conclusion qu'un remblai mou peut contenir la force de la rupture en laboratoire. On a examiné l'importance de ce phénomène par rapport aux problèmes à l'échelle de la mine du contrôle des ruptures de piliers.

---

*Chercheur scientifique, Laboratoire d'Elliot Lake, CANMET, Énergie, Mines et Ressources Canada.

OBJECT OF TESTS

To investigate the properties of cemented tailings backfill in providing lateral support to pillars undergoing failure in a 500 kN laboratory testing machine.

INTRODUCTORY REMARKS

Elliot Lake Quartzite is an extremely brittle rock which fails violently when loaded in a conventional "soft" machine. While little data are available for controlling the violence of failure through the use of oil confinement and a "stiff" machine, a comparable example is given in Figure 1. This serves to show that non-violent failure can be obtained given a machine stiffness of 3.9 GN/m and oil confining stresses upwards of 3 MPa. The peak/post-peak behaviour is, however, characterized by:

a) increased peak strength with confinement;

b) confining stresses > 10 MPa to achieve significant residual strength.

For the present test work the confining medium is cemented tailings and the loading machine is comparatively "soft", with a stiffness of 0.38 GN/m. For the range of cement contents tested the backfill classifies as "soft fill" according to Blight and Clarke's Figure 3 (Ref. [2]). On Figure 4 in the same reference it is indicated that a vertical stress in the fill of approximately 18 MPa should provide 10 MPa of lateral support. Assuming the same mechanism is at work to control the violence of failure, whether oil or backfill is the confining medium, 18 MPa will be taken as the vertical stress likely to produce significant post-failure strength and stability.

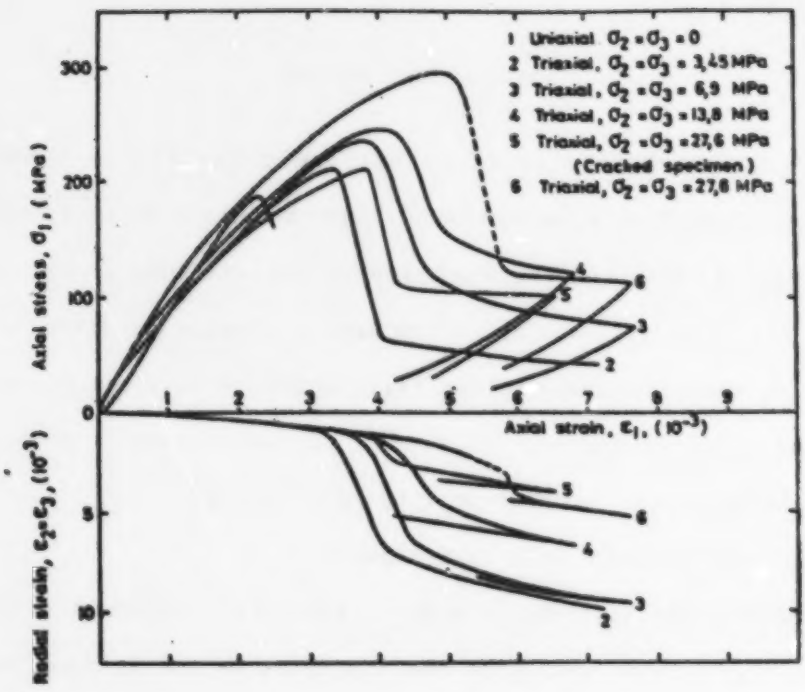

Figure 1 - Post-failure behaviour of Witwatersrand Quartzite at different oil confining pressures, after [1].

EXPERIMENTS

The experiments performed to date follow closely the method outlined in Ref.[2]. Briefly this comprised the following procedure:

1. Prepare rock core, diameter 44 mm and width:height ratio of 0.5.
2. With core positioned concentrically in a steel ring, inside diameter D, the cemented tailings was mixed at a moisture content of 20% and compacted around the core. The degree of compaction was such as to achieve a void ratio of 0.60 (a result based upon in-situ measurements, Ref. [3]).
3. Sample was sealed in plastic cover and cured for 7 days at room temperature.
4. Sample was removed from seal and loaded in a 500 kN press using a flat steel disc of which the diameter was slightly less than D. Total press load and axial deformation were monitored continuously until a strain of 2% was achieved. The set-up is shown diagrammatically in Figure 2.
5. In some samples the post-failure appearance of the enclosed core was observed by sectioning both ring and backfill.

A summary of the complete testing program is given in Table 1. It should be pointed out that in the interests of obtaining speedy results this is a limited program in many respects. In particular -

1. Strictly, no tests were repeated;
2. Load measured was aggregate load rather than true pillar load. The aggregate load is termed apparent pillar load below, since, providing the strains are small (<20 milli-strains), the approximation to true pillar load was found acceptable.

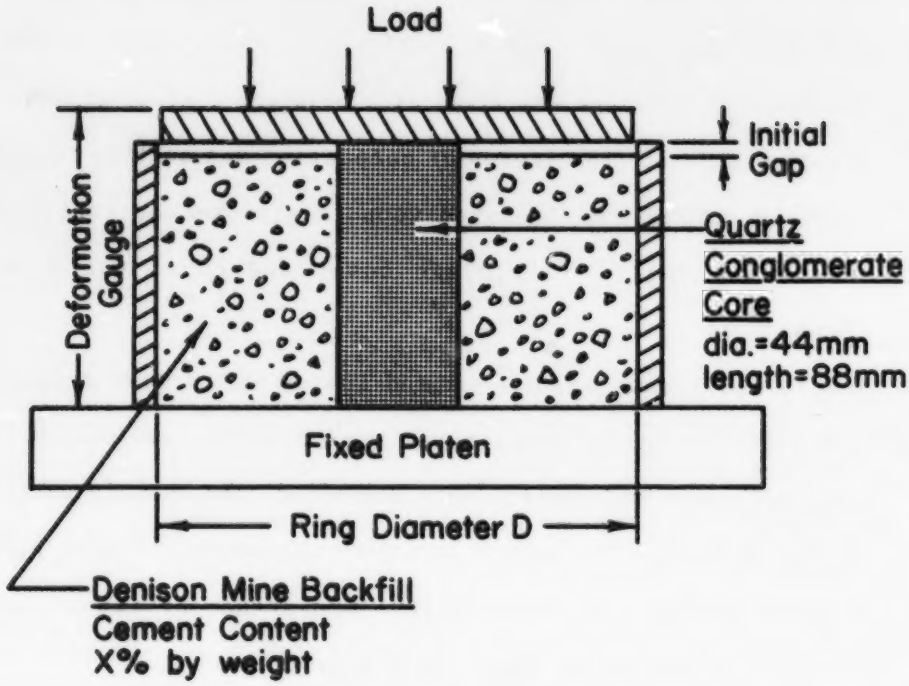

Figure 2 - Test set-up: Sectional diagram

Table 1 - Summary of Testing Program

Test Code	Ring Dia. D (mm)	Gap (mm)	Cement Content X(%)	Remarks
11	203	88.0	0	unconfined test
21	203	4.4	9.1(=10:1)	5% gap
22	203	0.0	9.1	tight
31	203	4.4	0.0	uncemented,5% gap
32	203	0.0	0.0	uncemented,tight
41	203	1.8	6.3(=15:1)	2% gap
42	203	6.3	6.3	tight
51	203	1.8	6.3/9.1/6.3	layered,2% gap
52	203	0.0	6.3/9.1/6.3	layered,tight
61	146	1.8	6.3	2% gap
62	146	0.0	6.3	tight
71	203	0.0	9.1	backfill only

TEST RESULTS

The raw load-deformation results from each of the 12 tests were corrected for interface and platen deformation effects. In the case of the tests coded 41, 42 and 51 the results were rejected because of pillar failure on a weakness plane. Failure under this condition occurred at only moderate loads and was stable in every case. For the purposes of comparison these data were not considered useful.

After classifying the remaining data into three types - unstable, no post-failure; unstable, some post-failure; stable post-failure - the results

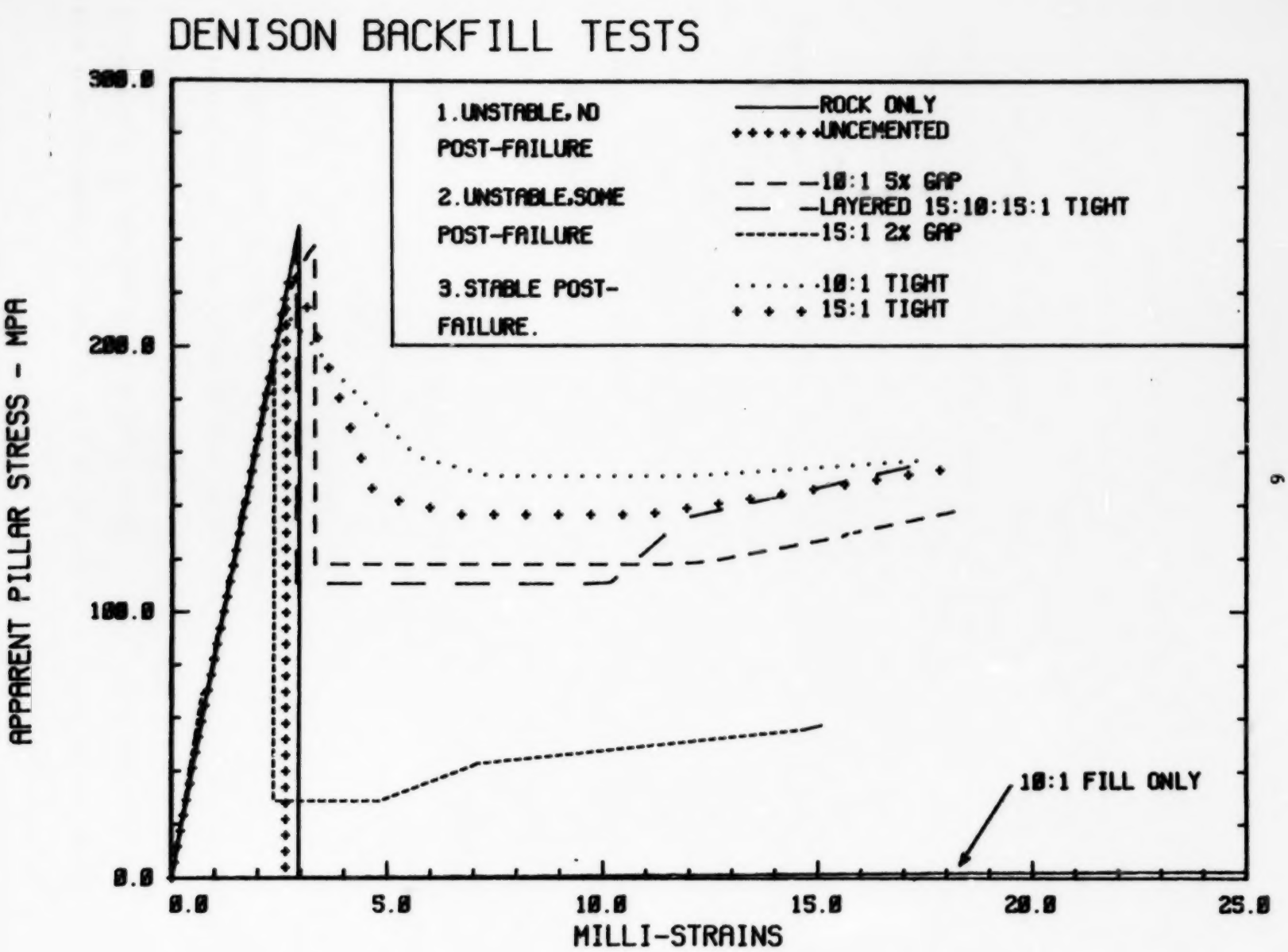

Figure 3 - Stress-strain curves recovered from pillar-backfill confinement tests

were plotted as stress-strain curves, Figure 3.

The sectioned specimens revealed that little or no "barrelling" had occurred; however, considerable vertical splitting was evident. No failure surfaces were observed in the backfill at or close to the rock interface.

DISCUSSION

A careful examination of the results, Figure 3, suggests that the violent failure typical of an unconfined test (depicted by a post-peak vanishing load) can be controlled without resorting to either a stiff machine or a "stiff" [2] fill. The result from test 71 clearly shows that lateral stresses of the order of 10 MPa could not have been instrumental in controlling failure where control is evident. The controlling mechanism does, however, require that:

1. The fill be cemented, and
2. The fill be tight initially to ensure simultaneous loading of rock and fill.

Reference to Figure 3 indicates that the second of these requirements serves to ensure non-violent behaviour during the <u>immediate</u> post-peak unloading. Appreciable residual strengths - upwards of 50% failure stress - can still be attainable when this requirement is relaxed. The value of cement content determines the level of residual strength attainable for a given gap. Thus, a tight 15:1 backfill provided a residual strength of approximately 120 MPa compared to 140 MPa for 10:1.

A possible mechanism which seems capable of explaining these observations is one involving buckling of the multiple slender columns comprising a split-failed pillar. In this case only moderate lateral stresses are required to maintain a stable condition. The generation of a vertical column "splitting" failure mode may be due to reduced end confinement effects

under transient load conditions. Such load conditions may, in turn, be unique to soft loading machines. At this time, however, further work is required to clarify the details of such a mechanism.

In order to discuss the significance of the above results in relation to the more complicated problems faced by Denison Mine, the following should be appreciated:

1. Although limited geometrical similitude can be obtained between the laboratory and mine systems with respect to width/height ratio and extraction ratio, the overall configurations are not similar. The laboratory results assume that the post-failure response of a single pillar is independent of the surrounding pillars;
2. The strength and stability of a pillar undergoing failure is strongly affected by induced confinement at the floor and roof interface. This effect in mine pillars is not easily quantified, depending upon width/height ratio and the frictional properties at the interface. Since the pillar failure mechanism in the above laboratory tests is not easily explained on the basis of active backfill confinement, the nature of induced confinement effects is probably crucial;
3. Field evidence from post-pillar mining clearly demonstrates that uncemented backfill provides for significant residual strengths [4]. The only known similarity between such mine configurations and the present experiments relates to the low width/height ratio. To what extent slenderness is critical to the role of backfill support is important since the majority of pillars at Denison Mine have a width/height ratio greater than 1.0.

REFERENCES

1. Hojem,J.P.M., Cook, N.G.W. and Heins,C., "A stiff, two meganewton testing machine for measuring the work-softening behaviour of brittle materials"; S. Afr. Mech. Eng., 25, Sept., 1975.

2. Blight,G.E. and Clarke,I.E., "Design and properties of stiff fill for lateral support"; Proc Int Symp Mining & Backfill/Lulea/7-9 June, 1983.

3. "A computer model to predict the free standing height of backfill in pillar recovery operations"; Dames & Moore Contract Report for CANMET, March, 1978.

4. Singh,K.H. and Hedley,D.G.F., "Review of fill mining technology in Canada"; Proc App Rock Mechanics to Cut-and-Fill Mining; IMM publication, 1981.

5. Schell,D.G., Inter-Office Memorandum on Cemented Tailings Backfill Tests; Rio Algom Ltd., June 28th, 1971.

APPENDIX

Uniaxial Compressive Strengths of Denison Mine Backfill

The results from uniaxial compression tests on 10:1 cemented Denison Mine tailings after 7 day curing are as follows:

Dry Bulk Density (kg/m^3)	1765.5
Void Ratio (-)	0.59
Moisture Content (%)	5.6
Compressive Strength (MPa)	1.02
Deformation Modulus (GPa)	0.15

Concerning in-situ strengths it is expected that the results obtained by Rio Algom in 1971 [5] could be relevant. This statement is made on the basis of a particle size distribution which is similar to that used by Denison (see Figure A1).

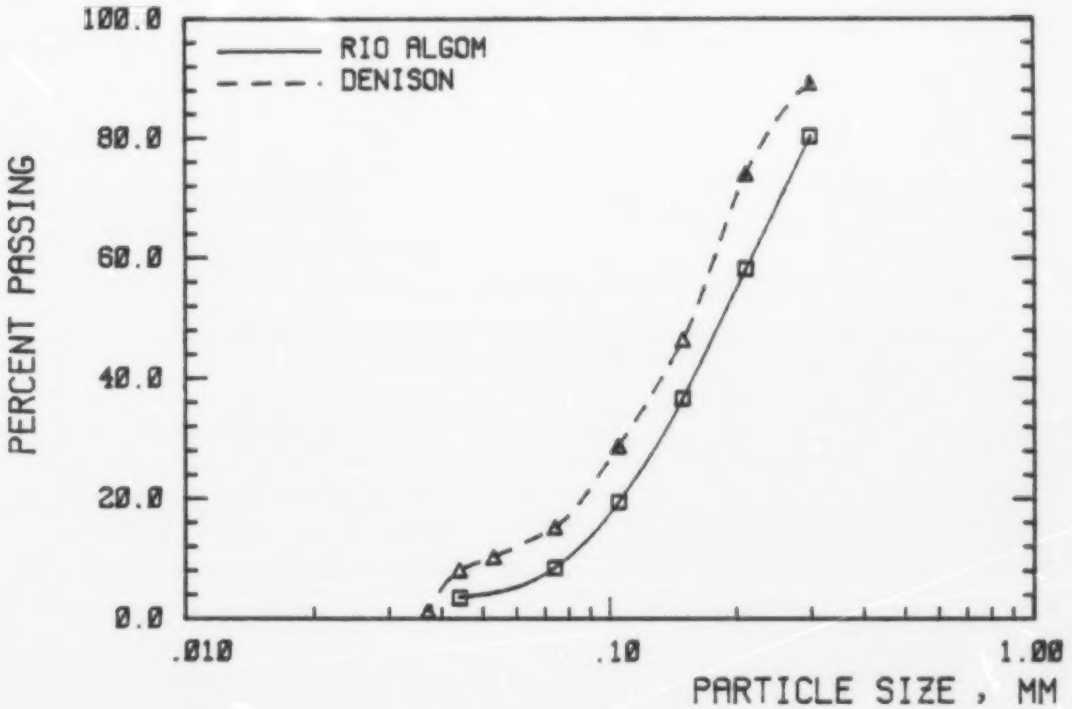

Figure A1 - Comparison of Rio Algom's tailings size distribution [5] and Denison's in current use.